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[54] **APPARATUS AND METHOD FOR HANDLING FRAGILE SEMICONDUCTOR WAFERS**

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[52] **U.S. Cl.** **156/584**; 156/381; 156/389; 156/344; 156/305; 156/155; 156/152; 51/235; 29/25.01; 279/3; 269/21

[58] **Field of Search** .... 51/235; 29/25.01, 402.03, 29/762, 764, ; 279/3; 269/21; 437/226; 156/155, 152, 305, 391, 344, 381, 389, 584

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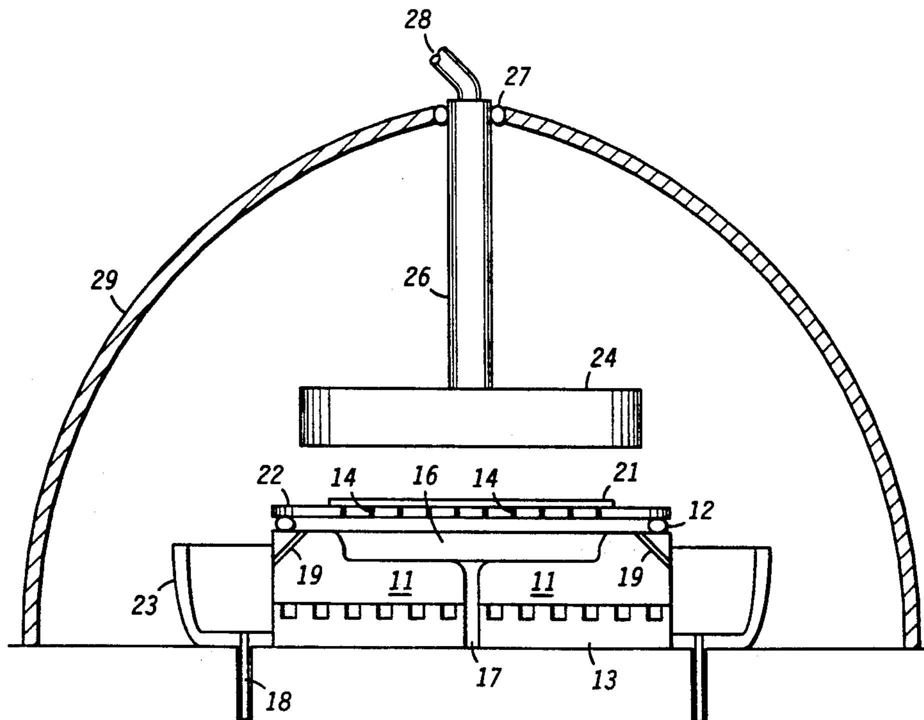
[57] **ABSTRACT**

An apparatus (**60**) which handles fragile semiconductor wafers (**21**) adhesively mounted to a submount (**22**) using a high temperature wax is provided. The apparatus (**60**) includes a vacuum chuck (**24**) for holding a first surface of the wafer (**21**) and a solvent chamber (**11, 11'**) for applying solvent to the back surface of the submount (**22**). The apparatus (**60**) includes an enclosure (**29**) for providing an inert gas environment around the solvent chamber (**11, 11'**), the wafer (**21**), and the vacuum chuck (**24**). The apparatus (**60**) further includes a means for remounting (**30**) the wafer (**21**) to a submount (**22**) using a low temperature wax after the high temperature wax is dissolved. The wafer (**21**) is then released from the vacuum chuck (**24**) and the first surface of the wafer (**21**) is mounted to an adhesive tape (**34**). Following the mounting, the low temperature wax is dissolved or melted to demount the wafer (**21**) from the submount (**22**), leaving the wafer (**21**) securely mounted on the adhesive tape (**34**) for sawing.

14 Claims, 2 Drawing Sheets



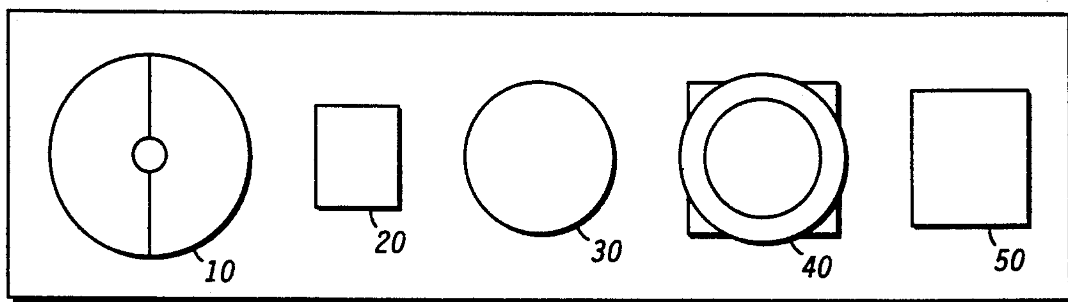


FIG. 1

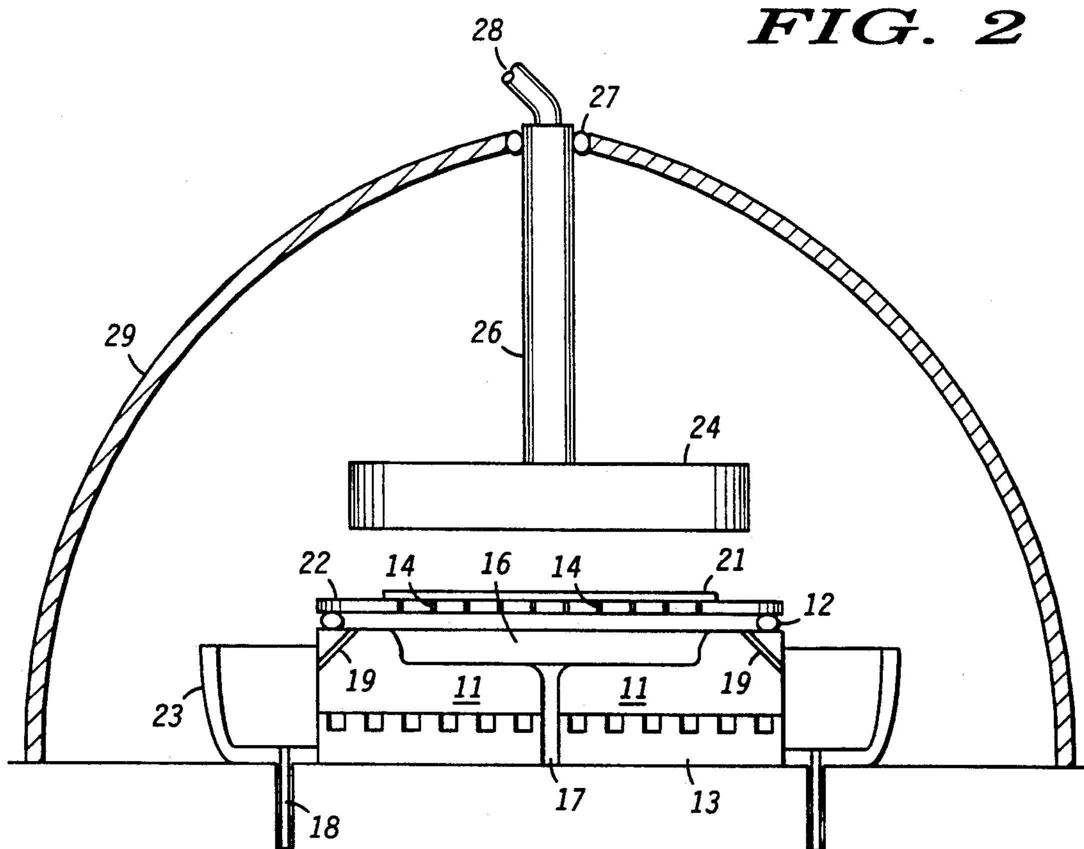


FIG. 2

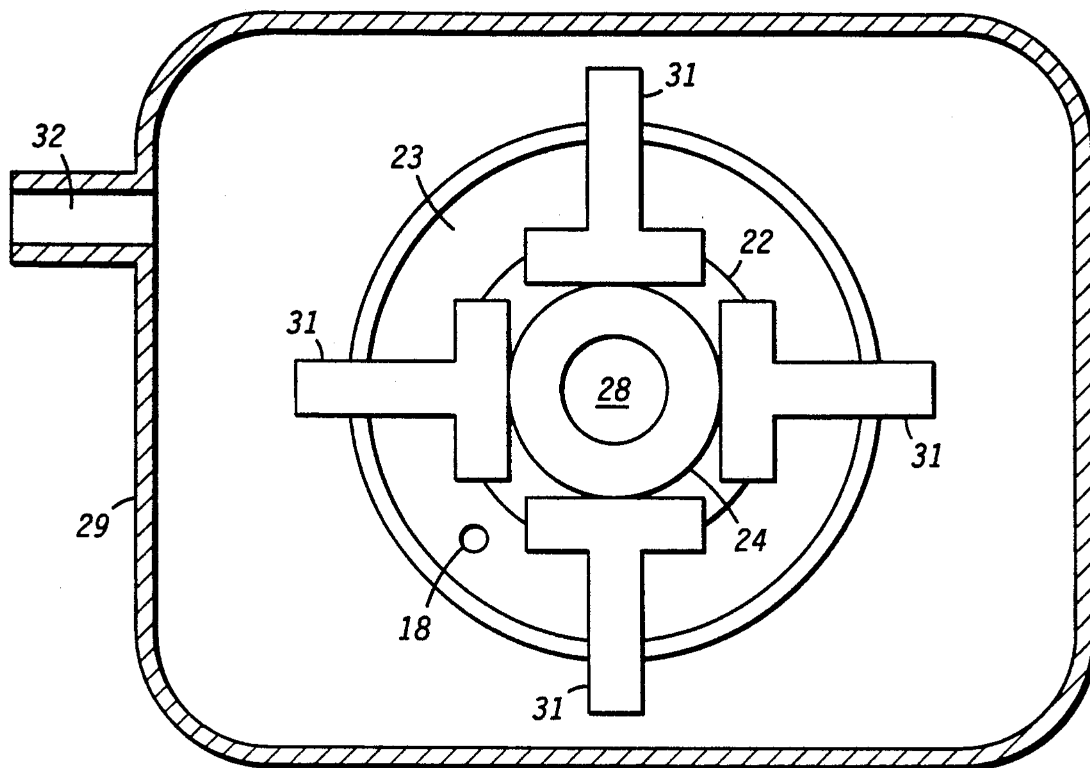
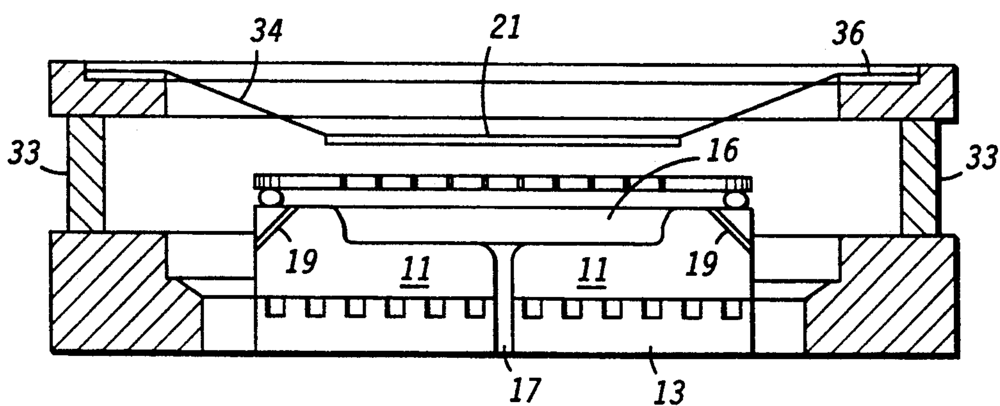


FIG. 3

FIG. 4



APPARATUS AND METHOD FOR HANDLING FRAGILE SEMICONDUCTOR WAFERS

BACKGROUND OF THE INVENTION

The present invention relates, in general, to semiconductor wafer handling, and more particularly, to an apparatus and method for handling very thin and fragile semiconductor wafers.

An array of semiconductor wafer handling equipment is available and works quite well for a large number of semiconductor processing needs. Increasing circuit density increases heat generated by the circuit. To remove this heat from integrated circuits manufacturers use thinner and thinner semiconductor wafers. These thinner wafers break easily, and thus demand more from semiconductor wafer handling equipment. This problem is more acute in the case of compound semiconductors, particularly gallium arsenide (GaAs) which is a factor of two and a half times as brittle as silicon.

Because devices manufactured on GaAs wafers typically operate at high frequencies, flatness and thickness uniformity become more important determinants of electrical performance than is true in silicon devices. Much of the special equipment needed for handling thinned GaAs wafers never had to be developed for silicon manufacturing. Handling of thinned GaAs wafers currently involves a large amount of manual handling, including moving the wafers by sliding them from one flat surface to another. Moreover, manual handling requires special skill and still results in unacceptable damage to the wafers.

Semiconductor wafers can be adhesively mounted on a submount or "handle" which provides a rigid platform to support the fragile wafer and allow automated handling. One problem with submounting, however, is that the wafer must at some point be removed from the submount. In the past, waxes have been used as an adhesive. These waxes had to have a low melting temperature, however, to allow the wax to be melted to remove the wafer from the submount, and to ensure that the wax could be cleaned from the wafer surface. An example of such a process is described in an article entitled "The Direct Demount of Thinned GaAs Wafers to Sawing Tape" by William C. Howell, published in the Proceedings of the Conference on Gallium Arsenide MANufacturing TECHnology (MANTECH), 1990. One problem with low temperature waxes is that they break down, melt, or dissolve during conventional wafer processing such as grinding the back side of the wafers. Alternatively, adhesive tape is used to mount the wafers to the submount. Adhesive tape, however, is difficult to work with, relatively expensive, can distort the shape of the thinned wafer, and results in an unacceptable number of broken wafers if automated taping equipment is used.

What is needed is an apparatus and method for handling fragile semiconductor devices in an automated fashion with minimal wafer breakage.

SUMMARY OF THE INVENTION

Briefly stated, the present invention is achieved by an apparatus which handles fragile semiconductor wafers adhesively mounted to a submount using a high temperature wax. The submount has a plurality of holes formed therein allowing liquid to pass from the back surface of the submount to the wax. The apparatus includes a vacuum chuck for holding a back surface of the wafer and a solvent chamber for applying solvent through the back surface of the submount. An annular seal of the solvent chamber prevents solvent from reaching the wafer and vacuum chuck directly.

In another embodiment, the apparatus includes an enclosure for providing an inert gas environment around the solvent chamber, wafer, and vacuum chuck. The apparatus further includes a means for remounting the wafer to a submount using low temperature wax after the high temperature wax is removed from the front side of the wafer. The wafer is then released from the vacuum chuck and the back surface of the wafer is mounted to an adhesive dicing tape. Following the mounting, the low temperature wax is dissolved or melted to demount the wafer from the submount, leaving the wafer securely mounted on the dicing tape for sawing.

As used herein, the term "high temperature wax" is used to mean a wax having a melting point above approximately 140° C., and the term "low temperature wax" is used to mean a wax having a melting point below approximately 90° C.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a highly simplified layout of a wafer handling apparatus in accordance with the present invention;

FIG. **2** is a cross-sectional view of a solvent demounting station of the apparatus shown in FIG. **1**;

FIG. **3** is a top-view of the solvent demounting station shown in FIG. **2**; and

FIG. **4** is a cross-section of a tape applicator demounter station.

DETAILED DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a highly simplified layout of a wafer handler in accordance with the present invention. While the present invention is illustrated as an assembly line, it should be understood that some of the discrete process steps shown in FIG. **1** can be integrated to reduce the total number of processing stations in the apparatus. For ease of understanding, however, each process step is illustrated as performed at a unique processing station. Also, the processing stations may be arranged in a linear, circular, or other arrangement to fit particular needs of a manufacturing environment.

The present invention is particularly useful for handling semiconductor wafers which are thinned by grinding and polishing a back side of the wafer. Prior to the thinning steps, the wafers are mounted to a rigid submount using adhesive wax. As will be seen, any adhesive which can be dissolved in solvent and which provides adequate adhesion is acceptable for purposes of the present invention. Although useful for many wafer handling operations, the present invention will be described with reference to a difficult handling process required to transfer the wafers from the submount to an adhesive dicing tape. Adhesive dicing tape is commonly used to support thinned wafers during sawing.

Details of each element of handler **60** shown in FIG. **1** are illustrated and described in greater detail in reference to the other drawings. FIG. **1** provides a general overview of the function and interaction of the component elements of apparatus **60**. Apparatus **60** includes a solvent demounting station **10**. Demounting station **10** is used to dissolve a high temperature wax adhesive and to

transfer a semiconductor wafer from a submount to a vacuum chuck. Once the wafer is securely grasped by the vacuum chuck a solvent clean processing station **20** completes removal of the high temperature adhesive wax. Solvent clean station **20** is not needed if wafers leaving demounting station **10** are free of adhesive wax.

Soft remount station **30** serves to remount the wafer to the submount using a low temperature water soluble wax, or other low temperature water soluble adhesive. Unlike high temperature adhesives, the low temperature adhesive can be removed by processes compatible with the adhesive tape used in saw tape applicator station **40**. As set out in the background, low temperature adhesive wax, while compatible with the saw tape applicator operation, is inadequate for grinding and back metal sputtering operations, which require an adhesive that can withstand high temperatures.

The wafer is mounted to adhesive saw tape in the saw tape applicator and demount station **40**. Demount station **40** also dissolves the low temperature adhesive wax with a warm water solution, so that the wafer remains supported by the saw tape. A water clean station **50** is also included, but is not needed if the low temperature adhesive wax is cleaned from the wafer during the demount operation. Once mounted on saw tape, the wafer is ready for further assembly processing.

FIG. **2** illustrates a portion of solvent demounting station **10** shown in FIG. **1**. Wafer **21** has a front side or first surface having a plurality of semiconductor devices formed therein. The front side of wafer **21** is mounted on submount **22** using an adhesive wax prior to processing on the apparatus shown in FIG. **1**. Wafer **21** may be thinned by grinding and polishing a back surface of wafer **21**, and metallization may be applied to the back surface of wafer **21** before processing on the apparatus shown in FIG. **1**.

Submount **22** includes a plurality of holes **14** which allow solvent to pass from a bottom or back surface of submount **22** to a top or front surface of submount **22**. In a preferred embodiment submount **22** comprises a material having a similar thermal expansion coefficient as wafer **21** and has several hundred small holes **14** machined through it. Because the adhesive wax (not shown) lies between wafer **21** and submount **22**, the wax is exposed to liquid flowing in holes **14**.

Mounting the semiconductor wafer to the submount is achieved by coating the top surface of the wafer with an adhesive wax. The adhesive wax is uniformly applied by spin coating, but other coating processes are known. The wax coated wafer is then placed front side down on the submount. The wafer and submount are heated to melt the wax, and cooled to solidify the wax, thereby bonding the wafer to the submount. The mounting, polishing, and metallization processes involve techniques that are known in the semiconductor arts. For example, a method of wax mounting wafers is described in U.S. Pat. No. 4,316,757 issued to R. Walsh on Feb. 23, 1982, and incorporated herein by reference.

Solvent chamber **11** comprises a solvent resistant material such as stainless steel. Chamber **11** is machined to provide a cavity **16** for holding solvent. An annular portion of chamber **11** surrounds cavity **16** and provides a flat surface for seal **12**. Seal **12** conveniently comprises a solvent resistant O-ring or the like. Seal **12** is shaped to provide a solvent-tight seal against the back surface of submount **22** such that holes **14** are over cavity **16** of solvent chamber **11**. Submount **22** is pressed against seal **12** to direct solvent through holes **14**.

Solvent chamber **11** is preferably heat resistant and thermally conductive so that disk heater **13** may be positioned on and thermally coupled to a bottom surface of solvent chamber **11** to heat solvent in cavity **16**. In a preferred embodiment, solvent is also heated prior to entering cavity **16**, and heater **13** is used to maintain the solvent temperature. Inlet **17** allows cavity **16** to be filled with solvent. During operation, the adhesive wax between wafer **21** and submount **22** is dissolved and solvent flows through holes **14**, across a top surface of submount **22** and to a solvent drain **18** located outside of solvent chamber **11**.

The high temperature solvent, operating at 170° C., for example, is very strong, thereby reducing the time required to dissolve the high temperature wax. The heat melts the high temperature wax, allowing it to flow. Because the wax is flowing, the solvent dissolves the wax rapidly and uniformly allowing wafer **21** to release from submount **22** quickly without undue stress. The combination of high temperature to melt the wax and a solvent to dissolve the wax is a key feature of this embodiment of the present invention. This feature of the present invention reduces the time required to separate wafer **21** from submount **22** to less than a minute in most applications.

Preferably, the solvent is recirculated in a closed-loop system, with additional solvent added at a rate determined by process experience. In some applications it may be desirable to circulate solvent in cavity **16** during operation to speed dissolution of the adhesive wax between wafer **21** and submount **22**. Circulation can be achieved by placing solvent outlets **19** in chamber **11** to allow solvent to flow and circulate before the adhesive wax begins to dissolve. Alternatively, magnetic or mechanical stirring tools or other known circulation methods can be used inside solvent cavity **16**. A solvent well **23** surrounds solvent chamber **11** to capture solvent as it leaves chamber **11** and direct the solvent towards solvent drain **18**.

The back surface of wafer **21** is grasped by vacuum chuck **24**, while the front surface remains adhesively attached to submount **22**. A robot arm or handle **26** is attached to chuck **24**. A portion of handle **26** extends outside of enclosure **29**, allowing some movement of chuck **24** during operation. A vacuum line **28** runs through a central portion of handle **26** and supplies the vacuum used by chuck **24** to grasp wafer **21**.

In operation, wafer **21** is secured by vacuum chuck **24** as solvent is applied to the adhesive wax. As wafer **21** detaches from submount **22** it remains supported by vacuum chuck **24** and wafer damage is avoided. Chuck **24** can be weighted so that wafer **21** remains in the flowing solvent after wafer **21** has detached from submount **22**, allowing the solvent to clean additional adhesive wax from wafer **21**. Also, this cleaning operation can be performed in a similar manner at solvent cleaning station **20** shown in FIG. **1**. Cleaning station **20** may use a room temperature solvent, for example, so that residual high temperature wax is removed from wafer **21** in a few minutes. The construction and operation of solvent cleaning station **20** are well understood in the art, and are not described in greater detail here.

In a preferred embodiment an enclosure **29** surrounds chuck **24**, wafer **21**, submount **22** as well as solvent chamber **11** and other components shown in FIG. **2**. A seal **27** is positioned between enclosure **29** and handle **26**. Enclosure **29** is filled with an inert gas, such as dry nitrogen, to prevent ignition of solvent fumes. This

allows the solvent to be heated beyond its flash point in oxygen or air. Also, because hot solvent is used, high temperature wax, such as glycol phthalate, can be used to bond wafer **21** to submount **22**. High temperature wax is more durable and has resistance to many semiconductor processes, thus increasing the number and variety of processes which can be performed while wafer **21** is mounted to submount **22**. For example, grinding, polishing, and metal depositions can be performed even though wafer **21** is quite fragile. Enclosure **29** is only one example of a safety feature which may improve performance of the present invention, and other known safety techniques for dealing with hot solvent vapors may also be used.

FIG. **3** illustrates a top view of the solvent demounting station **10** shown in FIG. **2**. Handle **26** extends upward from a central portion of chuck **24**. Chuck **24** hides wafer **21** in FIG. **3**. A portion of submount **22** extends beyond chuck **24** so that submount pinning arms **31** can apply downward pressure on submount **22**. Pressure applied by submount pinning arms **31** ensures that submount **22** seals against seal **12** shown in FIG. **2**. Solvent well **23** and solvent drain **18** are positioned as described hereinbefore. Enclosure **29** can be any convenient shape, and preferably includes an exhaust **32** to prevent buildup of solvent fumes inside chamber **29**.

Once wafer **21** is separated from submount **22** and cleaned, it is remounted onto submount **22** using a low temperature wax at soft remount station **30** shown in FIG. **1**. Wafer **21** is transported either by hand or using a mechanical transport system. Remounting involves coating the front side of wafer **21** with a low temperature wax such as LV-30 manufactured by Speedfam. Preferably, the wax is liquified in a solvent such as acetone and applied to the wafer by spin coating. The remount process of the present invention does not require a high degree of wax flatness or uniformity, but these features are desirable. Remounting is accomplished by melting the low temperature wax and pressing wafer **21** into the surface of submount **22**. Submount **22** is then cooled to solidify the wax.

A great deal of design latitude is permissible for remount station **30** using well known technology, and so construction and operation will not be discussed in greater detail here. Soft remount station **30** can be constructed simply by providing a hot plate or disk heater on which the remount operation takes place. An example of a method and apparatus for wax mounting of thin wafers is shown in U.S. Pat. No. 4,316,757 issued to Robert J. Walsh on Feb. 23, 1982.

Once wafer **21** is remounted to submount **22** using low temperature wax, wafer **21** is released from vacuum chuck **24** and the wafer-submount assembly can be transferred to tape applicator and demount station **40**. Transfer can be accomplished by hand or by well known transport mechanisms such as belts, cables, an arm, or the like. A cross-sectional view of the tape applicator and demount station **40** is shown in FIG. **4**. The demount portion of tape applicator and demount station **40** is substantially the same as solvent demounting station **10** in construction and operation. Because demount station **40** uses only water or mild solvents and operates at lower temperatures than solvent demounting station **10**, material requirements are less stringent and an enclosure similar to enclosure **29** shown in FIG. **3** is not needed. Portions of demount station **40** which operate in a similar manner to solvent demounting station **10** are designated with the same reference numeral as used in FIG. **2** but bear a prime designation in FIG. **4**.

Tape applicator and demount station **40** also includes a tape frame holder **33** which is constructed of a rigid material such as stainless steel and is shaped to hold tape frame **36**. Tape frame **36** is usually constructed of plastic or stainless steel and is shaped to fit into a groove machined in the surface of tape frame holder **33**. An area of adhesive mounting tape **34**, also called saw tape, is stretched onto tape frame **36** as is conventionally done in semiconductor device manufacturing. The exposed surface of wafer **21** is attached to tape **34**. Submount **22** is clamped to the annular portion of chamber **11'**.

In a preferred embodiment, cavity **16'** is filled with warm deionized water through inlet **17'**. The water is kept warm by heat from disk heater **13'**. The water melts and dissolves the low temperature wax through holes **14** in submount **22**. Once all of the low temperature wax is dissolved, wafer **21** is released from submount **22** and supported by tape **34**. Tape frame **36** is then removed from tape frame holder **33**, and tape frame **36**, tape **34**, and wafer **21** are transported to subsequent operations, such as cleaning or sawing.

The front side of wafer **21** may be cleaned with warm water to remove the residual low temperature wax in water clean station **50** shown in FIG. **1**. Water clean station **50** comprises, for example, a commercially available scrubber with an infrared heater. It may also be desirable to coat wafer **21** with photoresist or a similar coating to protect circuits formed on wafer **21** from damage during the saw operation. Such a coating can be applied by spin coating the entire frame, tape, and wafer assembly.

By now it should be appreciated that an apparatus and method for handling fragile semiconductor wafers is provided. Further, the apparatus in accordance with the present invention allows the use of process resistant high temperature waxes and improves throughput by decreasing the time required to separate semiconductor wafers from submounts or handle wafers. The method of handling fragile wafers in accordance with the present invention provides reduced breakage, minimal wafer damage, and a high degree of automated handling.

We claim:

1. An apparatus for handling a fragile semiconductor wafer comprising: a rigid submount having a front surface and a back surface opposite the front surface, wherein the semiconductor wafer has a first surface mounted to the front surface of the rigid submount by a high temperature adhesive, the wafer has a second surface which is exposed, and the rigid submount has a plurality of holes formed therein allowing liquid to pass from the back surface to the front surface; a vacuum chuck for holding the second surface of the wafer; a solvent chamber including a cavity for holding a pool of solvent, an annular portion surrounding the cavity, and an inlet coupled to the cavity for filling the cavity with solvent; and an annular seal on the annular portion of the solvent chamber, wherein the annular seal is shaped to provide a solvent-tight seal against the back surface of the rigid submount such that the plurality of holes in the rigid submount are over the cavity of the solvent chamber.

2. The apparatus of claim **1**, further comprising means for circulating the solvent in the cavity of the solvent chamber.

3. The apparatus of claim 1 further comprising an enclosure surrounding the vacuum chuck, the solvent chamber, and the rigid submount, wherein the enclosure is filled with an inert gas.

4. The apparatus of claim 3 wherein the inert gas is nitrogen.

5. The apparatus of claim 1 further comprising a heater thermally coupled to the solvent chamber for heating the pool of solvent.

6. The apparatus of claim 1, further comprising means for clamping the rigid submount against the annular seal.

7. An apparatus for handling a fragile semiconductor wafer, comprising:

a rigid submount having a front surface and a back surface opposite the front surface, wherein the semiconductor wafer has a first surface mounted to the front surface of the rigid submount by a high temperature adhesive, the wafer has a second surface which is exposed, and the rigid submount has a plurality of holes formed therein allowing liquid to pass from the back surface to the front surface;

a vacuum chuck for holding the second surface of the wafer;

a solvent chamber including a cavity for holding a pool of solvent, an annular portion surrounding the cavity, and an inlet coupled to the cavity for filling the cavity with solvent;

an annular seal on the annular portion of the solvent chamber, wherein the annular seal is shaped to provide a solvent-tight seal against the back surface of the rigid submount such that the plurality of holes in the rigid submount are over the cavity of the solvent chamber;

means for clamping the rigid submount against the annular seal;

means for remounting the wafer onto the rigid submount using a low temperature adhesive wax;

means for removing the remounted wafer from the vacuum chuck; and

means for attaching the second surface of the remounted wafer onto an adhesive tape.

8. The apparatus of claim 7 further comprising a means for dissolving the low temperature wax to separate the wafer from the submount.

9. The apparatus of claim 7 wherein the high temperature wax comprises glycol phthalate.

10. The apparatus of claim 7, further including means for circulating the solvent in the cavity of the solvent chamber.

11. The apparatus of claim 10, wherein the means for circulating the solvent in the cavity of the solvent chamber comprises a solvent outlet extending from the annular portion of the solvent chamber to a solvent well surrounding the solvent chamber.

12. The apparatus of claim 7, further comprising an enclosure surrounding the vacuum chuck, the solvent chamber, and the rigid submount, wherein the enclosure is filled with an inert gas.

13. The apparatus of claim 12, wherein the inert gas is nitrogen.

14. The apparatus of claim 7, further comprising a heater thermally coupled to the solvent chamber for heating the pool of solvent.

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